## TIME

**[1] Block, R. A. (1990b). Models of Psychological Time. In R. A. Block (Ed.), *Cognitive models of psychological time* (pp. 1–35). Hillsdale , NJ: Lawrence Erlbaum Associates.**

Abstract: *Reviews various models of psychological time the view of time as succession is reviewed by considering models that focus on phenomena related to the psychological moment, the psychological present, and memory for temporal order the view of time as duration is reviewed by considering models that focus on experienced and remembered duration, including chronobiological models, behavioral models, internal-clock models, attentional models, memory models, and a general contextualistic model.*

Notes: “Introductory chapter of Richard Block's "Cognitive Models of Psychological Time" provides comprehensive overview of the history of time perception research, including the most well-researched models of time as: succession, duration, and temporal perspective. Mandatory starting point for understanding of what research has been completed and that in progress.”

**[2] Hancock, P. A., & Block, R. A. (2012). 125th Anniversary Articles The Psychology of Time : A View Backward and Forward. *American Journal of Psychology*, *125*(3), 267–274.**

Abstract: *We selectively review the progress of research on the psychology of time during the past 125 American years, starting with the publication of the first English-language psychological journal, The Journal of Psychology. The psychology of time perception is a seminal topic of psychological science, and although it entered a phase of decline and even moribund neglect, the past several decades have seen a prominent renaissance of interest. This renewed vigor represents the rebirth of the recognition of the centrality of the psychology of time in human cognition and behavior. Our selective overview highlights a number of strands of progress and how they have helped lead to the present, in which the cognitive neuroscience of time and timing in the brain is one of the most fervent and fertile modern areas of brain research. We also discuss some remaining challenges and potential lines of progress.*

Notes: “Retrospective of psychological investigations of time since William James. Describes the decline of time research with the rise of behaviorism and the subsequent re-emergence with the cognitive revolution. Outlines pressing questions for future work. Good source of reference material.”

**[3] Pöppel, E. (1997). A hierarchical model of temporal perception. *Trends in Cognitive Sciences*, *1*(2), 56–61. doi:10.1016/S1364-6613(97)01008-5**

Abstract: *Temporal perception comprises subjective phenomena such as simultaneity, successiveness, temporal order, subjective present, temporal continuity and subjective duration. These elementary temporal experiences are hierarchically related to each other. Functional system states with a duration of 30 ms are implemented by neuronal oscillations and they provide a mechanism to define successiveness. These system states are also responsible for the identification of basic events. For a sequential representation of several events time tags are allocated, resulting in an ordinal representation of such events. A mechanism of temporal integration binds successive events into perceptual units of 3 s duration. Such temporal integration, which is automatic and presemantic, is also operative in movement control and other cognitive activities. Because of the omnipresence of this integration mechanism it is used for a pragmatic definition of the subjective present. Temporal continuity is the result of a semantic connection between successive integration intervals. Subjective duration is known to depend on mental load and attentional demand, high load resulting in long time estimates. In the hierarchical model proposed, system states of 30 ms and integration intervals of 3 s, together with a memory store, provide an explanatory neuro-cognitive machinery for differential subjective duration.*

Notes: “German perceptual psychologist Ernst Poppel presents a model for temporal perception based on neuro-cognitive evidence. Builds on his 1978 taxonomy of temporal experiences: simultaneity, successiveness, temporal order, subjective present, anticipation, temporal continuity and duration.”

## SPATIAL CONSTRUALS OF TIME

**[4] Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*(8), 1430–51. doi:10.1111/j.1551-6709.2010.01105.x**

Abstract: *Across cultures people construct spatial representations of time. However, the particular spatial layouts created to represent time may differ across cultures. This paper examines whether people automatically access and use culturally specific spatial representations when reasoning about time. In Experiment 1, we asked Hebrew and English speakers to arrange pictures depicting temporal sequences of natural events, and to point to the hypothesized location of events relative to a reference point. In both tasks, English speakers (who read left to right) arranged temporal sequences to progress from left to right, whereas Hebrew speakers (who read right to left) arranged them from right to left, replicating previous work. In Experiments 2 and 3, we asked the participants to make rapid temporal order judgments about pairs of pictures presented one after the other (i.e., to decide whether the second picture showed a conceptually earlier or later time-point of an event than the first picture). Participants made responses using two adjacent keyboard keys. English speakers were faster to make "earlier" judgments when the "earlier" response needed to be made with the left response key than with the right response key. Hebrew speakers showed exactly the reverse pattern. Asking participants to use a space-time mapping inconsistent with the one suggested by writing direction in their language created interference, suggesting that participants were automatically creating writing-direction consistent spatial representations in the course of their normal temporal reasoning. It appears that people automatically access culturally specific spatial representations when making temporal judgments even in nonlinguistic tasks.*

Notes: Do people access culturally specific representations even when not required to process or produce language? Previous work has shown that individuals construct differing spatial representations of time across different cultures. The purpose of this paper is to discuss whether people automatically access and use culturally specific representations when reasoning about time. Experiment 1 replicates previous work, showing that English speakers arranged temporal sequences (l->r) while Hebrew arranged (r->l) using a picture arrangement task. Experiment 2 asked participants to rapidly make earlier/later (S time) judgments in pairs of pictures. Response time was congruent with directionality of response key. English speakers responded more quickly when the key indicated "earlier" was to the left, and reverse for Hebrew. Authors conclude that asking participants to create a space-time mapping inconsistent with their culturally suggested representation creates interference, which suggests that Ss were automatically creating writing-direction consistent spatial representations in the course of their normal temporal reasoning. Therefore, these culturally specific representations are accessed even in non-linguistic tasks. Also found that results were present for a variety of temporal sequences (not only ones that are normally laid out on a calendar, in a culturally specific habituated spatial representation). They found that the size of the congruency depended on the relative duration of the depicted time interval: the longer the event, the larger the congruency effect. (88)

**[5] Núñez, R., & Cooperrider, K. (2013). The tangle of space and time in human cognition. *Trends in Cognitive Sciences*, *17*(5), 220–9. doi:10.1016/j.tics.2013.03.008**

Abstract: *Everyday concepts of duration, of sequence, and of past, present, and future are fundamental to how humans make sense of experience. In culture after culture, converging evidence from language, co-speech gesture, and behavioral tasks suggests that humans handle these elusive yet indispensable notions by construing them spatially. Where do these spatial construals come from and why do they take the particular, sometimes peculiar, spatial forms that they do? As researchers across the cognitive sciences pursue these questions on different levels--cultural, developmental--in diverse populations and with new methodologies, clear answers will depend upon a shared and nuanced set of theoretical distinctions. Time is not a monolith, but rather a mosaic of construals with distinct properties and origins.*

Notes: Much evidence from (linguistic, gesture, behavioral) tasks suggests that humans make sense of time through spatial metaphors. This paper reviews the findings to date. 1. Time perception must be distinguished from time conceptualization. 2. SCT = "spatial construal of time" Inspired by Whorfian hypotheses (Whorf, 1941) of linguistic determinism, where he contrasted European concepts of time and space vs. the Hopi Indian concept of time that was devoid of space. (Subsequently rebutted by linguistic analysis of Hopi). Current thinking is that language plays a role, but not to the extent as Whorf believed. 3. Conceptual metaphor is a popular lens through which to study the conception of space and time. Spatial reasoning influences temporal reasoning, but not vice versa in the same way. 4. A (D - deictic) and B (S – sequential series) time. 5. For both D and S series there is internal and external locus. (ego in the metaphor or as a third person observer).

**[6] Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*(4), 745–57. doi:10.1207/s15516709cog0000_67**

Abstract: *Flexibility in conceptual projection constitutes one of the most challenging issues in the embodiment and conceptual metaphor literatures. We sketch a theoretical proposal that places the burden of the explanation on attentional dynamics in interaction with mental models in working memory that are constrained to be maximally coherent. A test of this theory is provided in the context of the conceptual projection of time onto the domain of space. Participants categorized words presented at different spatial locations (back-front, left-right) as referring to the past or to the future. Responses were faster when the irrelevant word location was congruent with the back-past, front-future metaphoric mapping. Moreover, when a new highly task-relevant spatial frame of reference was introduced, it changed the projection of past and future onto space in a way that was congruent with the new frame (past was now projected to left space and future to right space), as predicted by the theory. This study shows that there is substantial flexibility in conceptual projection and opens a venue to study metaphoric variation across tasks, individuals, and cultures as the result of attentional dynamics.*

Notes: “Proposes explanation for flexibility of spatial conceptions of time via an attentional mechanism. Provides evidence from two experiments (independent factor analyses) to show that the choice of spatial mapping to time (for temporal order) was affected by the task demands presented (suggesting an attentional mechanism for maximal coherence was employed).”

**[7] Walker, E. J., Bergen, B. K., Núñez, R., Science, C., Bates, E., & Cohen, H. (2013). Investigating Spatial Axis Recruitment in Temporal Reckoning Through Acoustic Stimuli and Non-Spatial Responses of phonological processing. *Center for Research in Language Technical Report, University of California, San Diego*, *25*(1), 1–10.**

Abstract*: We talk about time using spatial terms ("ahead", "behind") and spatial gestures (front-back, left-right). Experimental investigation of such space-to-time mappings has focused primarily on the space in front of the participant, likely driven by the convenience of screen presentation and button responses. This has had two consequences: the disregard of the space behind the participant (exploited in language and gesture) and the creation of potential task demands produced by the spatialized manual button-presses. We present a new paradigm that addresses these issues. Participants, responding vocally, made temporal judgments about deictic (past, future) or sequential (earlier, later) relationships presented auditorily along a full front-back or left-right axis. Results involving the left-right axis replicated previous work. Participants mapped past and earlier judgments onto the left and future and later judgments to the right. Surprisingly, deictic judgments did not use the front-back axis but sequential judgments did, in a novel way. Participants mapped earlier judgments onto the space in front of them and later judgments onto the space behind them, which, to our knowledge has never been demonstrated. These findings suggest that different time conceptsWhat is the psychological reality of spatial construals of time? (gesture, language and non linguistic tasks)*

Notes: “Researchers have looked at compatibility effects along 2 axes: (transversal vs. sagittal). Transversal is consistent with direction of cultural technologies (ie. writing). Experimental evidence for sagittal axis is unclear, as studies (Furhman et all 2011, Sell & Kashak, 2010) do not find consistency with the linguistic and gestural observations of past behind and future in front.
Limitations of studies: - presentation modality (screen) and responses (buttons) limit use of sagittal axis - tasks demands of using button presses imposes use of space onto the respondents - lack of distinction between deictic and sequential time (McTaggart, 1908) Are D time and S time construed in systematically different manners? this paper proposes a novel paradigm (auditory stimuli and vocal responses) to investigate construals on both axes, looking at compatibility effects for both temporal concepts (deictic, sequential). Presents difference between "Career of Metaphor" and "Structural Similarity" hypotheses and "Conceptual Metaphor" theory as suggesting different experimental results. In the former, metaphor becomes highly conventionalized such that individuals do not actively think about space when talking about time in conventional ways. In the latter, the spatial-temporal mappings occur at the level of thought.

## METAPHOR

**[8] Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. Oxford University Press. doi:978-0226468013**

Abstract: *The now-classic Metaphors We Live By changed our understanding of metaphor and its role in language and the mind. Metaphor, the authors explain, is a fundamental mechanism of mind, one that allows us to use what we know about our physical and social experience to provide understanding of countless other subjects. Because such metaphors structure our most basic understandings of our experience, they are "metaphors we live by"—metaphors that can shape our perceptions and actions without our ever noticing them. In this updated edition of Lakoff and Johnson's influential book, the authors supply an afterword surveying how their theory of metaphor has developed within the cognitive sciences to become central to the contemporary understanding of how we think and how we express our thoughts in language.*

**[9] Boroditsky, L. (2000). Metaphoric structuring: understanding time through spatial metaphors. *Cognition*, *75*(1), 1–28.**

Abstract: *The present paper evaluates the claim that abstract conceptual domains are structured through metaphorical mappings from domains grounded directly in experience. In particular, the paper asks whether the abstract domain of time gets its relational structure from the more concrete domain of space. Relational similarities between space and time are outlined along with several explanations of how these similarities may have arisen. Three experiments designed to distinguish between these explanations are described. The results indicate that (1) the domains of space and time do share conceptual structure, (2) spatial relational information is just as useful for thinking about time as temporal information, and (3) with frequent use, mappings between space and time come to be stored in the domain of time and so thinking about time does not necessarily require access to spatial schemas. These findings provide some of the first empirical evidence for Metaphoric Structuring. It appears that abstract domains such as time are indeed shaped by metaphorical mappings from more concrete and experiential domains such as space.*

Notes: Extends Lakoff & Johnson (1980) Conceptual Metaphor Theory by proposing psychological model "Metaphoric structuring" and tests it with two experiments. Seeks to show that: (1) Space and time are conceptually related, (2) time can be thought of using spatial metaphors and (3) with frequent use, mappings between space and time come to be stored in the domain of time and so thinking about time does not necessarily require access to spatial schemas. Uses ego/time-moving construals of space & time in experimentation tasks (reaction time/interference and disambiguation of ambiguous stimuli). #890 citations.

## VISUALIZATION

**[10] Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science*, *3*(3), 499–535. doi:10.1111/j.1756-8765.2010.01113.x**

Abstract: *Depictive expressions of thought predate written language by thousands of years. They have evolved in communities through a kind of informal user testing that has refined them. Analyzing common visual communications reveals consistencies that illuminate how people think as well as guide design; the process can be brought into the laboratory and accelerated. Like language, visual communications abstract and schematize; unlike language, they use properties of the page (e.g., proximity and place: center, horizontal/up–down, vertical/left–right) and the marks on it (e.g., dots, lines, arrows, boxes, blobs, likenesses, symbols) to convey meanings. The visual expressions of these meanings (e.g., individual, category, order, relation, correspondence, continuum, hierarchy) have analogs in language, gesture, and especially in the patterns that are created when people design the world around them, arranging things into piles and rows and hierarchies and arrays, spatial-abstraction-action interconnections termed spractions. The designed world is a diagram.*

Notes: "Foundational article by Tversky; establishes conceptual framework for the role of visualization as it pertains to the use of space and form. Establishes an (implicit) connection to grounded/situated cognition. Includes references to experimental investigations with children from different cultures (Tversky, 1991)."

**[11] Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*, 515–557. doi:10.1016/0010-0285(91)90005-9**

Abstract: *How does space come to be used to represent non-spatial relations, as in graphs? Approximately 1200 children and adults from three language cultures, English, Hebrew, and Arabic, produced graphic representations of spatial, temporal, quantitative, and preference relations. Children placed stickers on square pieces of paper to represent, for example, a disliked food, a liked food, and a favorite food. Two major analyses of these data were performed. The analysis of directionality of the represented relation showed effects of direction of written language only for representations of temporal concepts, where left-to-right was dominant for speakers of English and right-to-left for speakers of Arabic, with Hebrew speakers in between. For quantity and preference, all canonical directions except top-to-bottom were used approximately equally by all cultures and ages. The analysis of information represented in the graphic representations showed an age trend; more of the older children represented ordinal and some interval information in their mappings. There was a small effect of abstractness of concept on information represented, with more interval information represented by children for the more concrete concepts, space, time, quantity, and preference in that order. Directionality findings were related to language-specific left-to-right or right-to-left directionality and to universal association of more or better with upward. The difficulties in externally representing interval information were related to prevalent difficulties in expressing comparative information. Children's graphic productions were compared to other invented notation systems, by children and by cultures, particularly for numbers and language.*

## MENTAL MODELS

**[12] Schaeken, W., & Johnson-Laird, P. N. (1995). Mental models and temporal reasoning. *Cognition*, *60*(96), 205–234.**

Abstract: *We report five experiments investigating reasoning based on temporal relations, such as: "John takes a shower before he drinks coffee". How individuals make temporal inferences has not been studied hitherto, but we conjectured that they construct mental models of events, and we developed a computer program that reasons in this way. As the program shows, a problem of the form:a before b, b before c, d while b, e while c, what is the relation between d and e? Where a, b, c, etc. refer to everyday events, calls for just one model, whereas a problem in which the second premise is modified to c before b calls for multiple models because a may occur before c, after c, or at the same time as c. Experiments 1-3 showed that problems requiring one mental model elicited more correct responses than problems requiring multiple models, which in turn elicited more correct answers than multiple model problems with no valid answers. Experiment 4 contrasted the predictions of the model theory with those based on formal rules of inference; its results corroborated the model theory. Experiment 5 confirmed that a premise leading to multiple models took longer to read than the corresponding premise in one-model problems, and that latency to respond correctly was greater for multiple-model problems than for one-model problems. We conclude that the experiments corroborate the mental model theory.*

Notes: "Provides conceptual basis for theory of mental model reasoning as applied to temporal reasoning. Experiments demonstrate that individuals have more performance error and take longer to reason when a scenario produces multiple possible models."

**[13] Johnson-Laird, P. N. (1999). Causation, Mental Models, and the Law. *Brooklyn Law Review*, (c), 1–31.**

Abstract: *Lawyers think about causal relations, because, as these examples show, liability can depend on causation. ... Each mental model represents a possibility, and its structure corresponds to the structure of what it represents. ... We conclude that the invocation of explanatory principles and generalizations is a useful way-perhaps the only way in many cases-to infer causation from correlation, but the resulting conclusion of a causal relation means no more than that a certain set of temporally-ordered possibilities obtains. ... The case is altered; the conclusion is false even if the premise is true. ... vapor <negation> spark <negation> explosion <negation> vapor spark <negation> explosion ... vapor <negation> spark <negation> explosion <negation> vapor spark <negation> explosion ... There is no causal relation here between spark and explosion, but the original set of models of the circumstances shows that the presence of the vapor enables the spark to cause the explosion, i.e.: ... spark <negation> vapor <negation> explosion ... they are granting that the causal relation holds unless some enabling condition is absent or some disabling condition is present. ...*

Notes: "Application of theory of mental model reasoning to the law, addressing legal theory for causation (legal cause, cause in effect, proximate cause). In particular, discusses difference and similarity between enabling conditions and cause."

## MISCELLANEOUS

**[14] Richmond, J., Wilson, Clare, J., & Zinken, J. (2012). A feeling for the future: How does agency in time metaphors relate to feelings? *European Journal of Social Psychology*, *823*(October), 813–823.**

Abstract: *Most cultures have metaphors for time that involve movement, for example, 'time passes'. Although time is objectively measured, it is subjectively understood, as we can perceive time as stationary, whereby we move towards future events, or we can perceive ourselves as stationary, with time moving past us and events moving towards us. This paper reports a series of studies that first examines whether people think about time in a metaphor-consistent manner (Study 1) and then explores the relationship between 'time perspective', level of perceived personal agency, and time representations (Study 2), the relationship between emotional experiences and time representation (Study 3), and whether this relationship is bidirectional by manipulating either emotional experiences (Study 4) or time representation (Study 5). Results provide bidirectional evidence for an ego-moving representation of time, with happiness eliciting more agentic control, and evidence for a time-moving passivity associated with emotional experiences of anxiety and depression. This bidirectional relationship suggests that our representation of time is malleable, and therefore, current emotional experiences may change through modification of time representations.*

**[15] Lebois, L. a M., Wilson-Mendenhall, C. D., & Barsalou, L. W. (2014). Are Automatic Conceptual Cores the Gold Standard of Semantic Processing? The Context-Dependence of Spatial Meaning in Grounded Congruency Effects. *Cognitive Science*, 1–38. doi:10.1111/cogs.12174**

Abstract: *According to grounded cognition, words whose semantics contain sensory-motor features activate sensory-motor simulations, which, in turn, interact with spatial responses to produce grounded congruency effects (e.g., processing the spatial feature of up for sky should be faster for up vs. down responses). Growing evidence shows these congruency effects do not always occur, suggesting instead that the grounded features in a word's meaning do not become active automatically across contexts. Researchers sometimes use this as evidence that concepts are not grounded, further concluding that grounded information is peripheral to the amodal cores of concepts. We first review broad evidence that words do not have conceptual cores, and that even the most salient features in a word's meaning are not activated automatically. Then, in three experiments, we provide further evidence that grounded congruency effects rely dynamically on context, with the central grounded features in a concept becoming active only when the current context makes them salient. Even when grounded features are central to a word's meaning, their activation depends on task conditions.*

**[16] Lakoff, G. (2012). Explaining embodied cognition results. *Topics in Cognitive Science*, *4*(4), 773–85. doi:10.1111/j.1756-8765.2012.01222.x**

Abstract: *From the late 1950s until 1975, cognition was understood mainly as disembodied symbol manipulation in cognitive psychology, linguistics, artificial intelligence, and the nascent field of Cognitive Science. The idea of embodied cognition entered the field of Cognitive Linguistics at its beginning in 1975. Since then, cognitive linguists, working with neuroscientists, computer scientists, and experimental psychologists, have been developing a neural theory of thought and language (NTTL). Central to NTTL are the following ideas: (a) we think with our brains, that is, thought is physical and is carried out by functional neural circuitry; (b) what makes thought meaningful are the ways those neural circuits are connected to the body and characterize embodied experience; (c) so-called abstract ideas are embodied in this way as well, as is language. Experimental results in embodied cognition are seen not only as confirming NTTL but also explained via NTTL, mostly via the neural theory of conceptual metaphor. Left behind more than three decades ago is the old idea that cognition uses the abstract manipulation of disembodied symbols that are meaningless in themselves but that somehow constitute internal "representations of external reality" without serious mediation by the body and brain. This article uniquely explains the connections between embodied cognition results since that time and results from cognitive linguistics, experimental psychology, computational modeling, and neuroscience.*